

# **A 1900-GHz LOCAL OSCILLATOR CHAIN FOR EXPANDED MULTI-PIXEL GALACTIC SURVEY ON THE STRATOSPHERIC THz OBSERVATORY**

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Final Report

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Imran Mehdi (PI), Instrument Electronics and Sensors Section (389)  
Chris Walker, Department of Astronomy, University of Arizona  
Choonsup Lee, Instrument Electronics and Sensors Section (389)

## **A. OBJECTIVES**

The objective is to design the next generation (post-HIFI) of a local oscillator (LO) source centered at 1900 GHz. This next-generation source is the enabling technology that would allow the potential to place an expanded, multi-pixel hot electron bolometer (HEB)–based heterodyne receiver system on an already funded long-duration balloon platform, Stratospheric Terahertz Observatory (STO). STO is a collaborative project among the University of Arizona (Walker-PI), JPL, Caltech, JHAPL, and several other institutions. The STO mission is funded by NASA's Astrophysics Research and Analysis (APRA) program. The initial observational goal of STO is to make high spectral ( $<0.1$  km/s) and angular resolution ( $\sim 1'$ ) maps of the Galactic Plane in the astrophysically important transitions of C+ at 1.9 THz and N+ at 1.46 THz. To achieve the angular resolution requirement, STO will have an aperture of  $\sim 80$  cm. To achieve the target spectral resolution, STO will utilize a heterodyne receiver system. The proposed LO development is the key element in determining the size of the receiver array. While the source developed for HIFI is sufficient to pump two HEB channels, the next generation source will deliver more than 10 microwatts of output power that should be sufficient to pump 4-8 HEB channels. The proposed source with its expanded receiver system could serve as the testbed for a THz instrument for the next round of MIDEX proposals.

## **B. APPROACH AND RESULTS**

To increase the output power at 1900 GHz, a number of steps have been taken. The approach that will be followed is shown in Figure 1. The proposed 1.9-THz LO source will be implemented as a  $2 \times 3 \times 3$  chain. We will design a 4-chip 200-GHz doubler that will provide 80 mW of output power. This will be used to pump a 2-chip 600-GHz tripler. It is expected that such a tripler will provide more than 5 mW of output power. We predict that this will be enough to pump the 1.9-THz tripler to produce more than 10 microwatts of output power. If possible, the chain can be cooled to 150 K to meet this goal. A 4-chip power amplifier module will be built using the approach shown in Figure 2. This block has already been built. Output power is expected to be in the 400 mW range around 106 GHz.

We recently demonstrated the use of multiple multiplier chips in a single waveguide block to increase output power. The 4-chip 200-GHz doubler design has been completed and blocks are being fabricated at the University of Arizona. This block will utilize four membrane-based doubler chips. The input signal is divided equally between four chips, whereas the output signal from the four chips is combined via a Y power combiner. Output power of 80 mW at 212 GHz is around a factor of 4 higher from what can be achieved with a single-chip membrane-based implementation. Each chip is expected to have around 20% efficiency, which will provide an ~80-mW signal at 212 GHz.

Power from the doubler will be used to pump a tripler working in the 600-GHz range. Results from a single-chip implementation are shown in Figure 3. Two blocks (SN3 and SN8) have been tested. A single block that uses two of these chips will be used to produce more than 5 mW to drive the final stage tripler. The 1900-GHz tripler chip has been designed to produce around 10 microwatts and is shown in Figure 4.

### **C. SIGNIFICANCE OF RESULTS**

The C+ line (at ~158 microns) is the strongest Galactic cooling line and will be the premier diagnostic tool for studying the life cycle of the interstellar medium (ISM) in the Milky Way and other nearby galaxies. The STO C+ survey, together with pointed observations from Herschel, will provide the “Rosetta Stone” for translating the global properties of distant galaxies into reliable estimators of star formation rate and state of the ISM. The observing strategy for the survey is to make adjacent on-the fly (OTF) strip maps of the Galactic Plane. The ultimate limiting factor for a larger pixel count array is the amount of available LO power. The results presented show that we have a scheme that can produce enough power to pump 4–10 HEB pixels for mapping of the Galactic Plane.

### **D. NEW TECHNOLOGY**

NTR number: 46567 — “A Quad-chip Double Balanced Frequency Tripler”

### **E. FINANCIAL STATUS**

The total funding for this task was \$98,900, all of which has been expended.

### **F. ACKNOWLEDGEMENTS**

Help from Bertrand Thomas, Robert Lin, Seth Sin, Alex Peralta, and Alain Maestrini is acknowledged.

### **G. PUBLICATIONS AND PRESENTATIONS**

- [A] Choonsup Lee, J. Ward, R. Lin, E. Schlecht, G. Chattopadhyay, J. Gill, B. Thomas, A. Maestrini, I. Mehdi, and P. Siegel, “A Wafer-level Diamond Bonding Process to Improve Power Handling Capability of Submillimeter-Wave

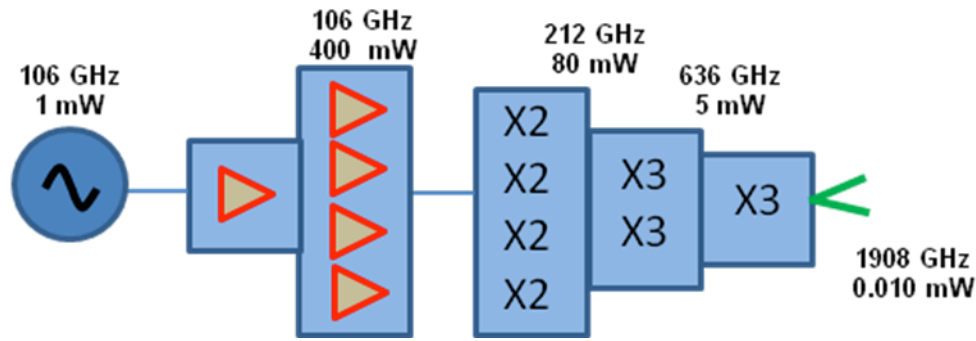
Schottky Diode Multipliers,” *Proceedings of the IEEE-IMS2009 Symposium*, Boston, Massachusetts, June 2009.

- [B] Imran Mehdi, John Ward, Alain Maestrini, Goutam Chattopadhyay, Erich Schlecht, Bertrand Thomas, Robert Lin, Choonsup Lee, and John Gill, “Broadband Sources in the 1–3 THz Range,” *Proceedings of the 34<sup>th</sup> International Conference on Infrared, Millimeter, and Terahertz Waves*, Busan, Korea, September 2009.

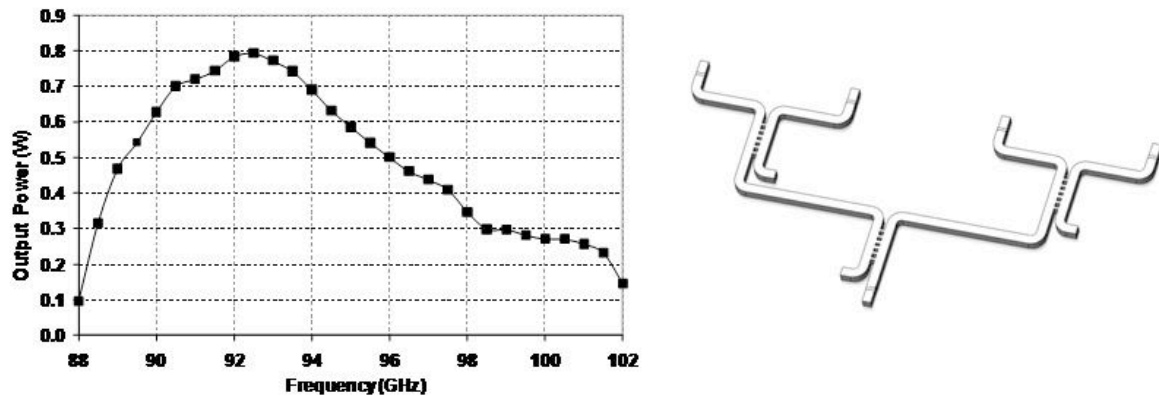
## H. REFERENCES

None.

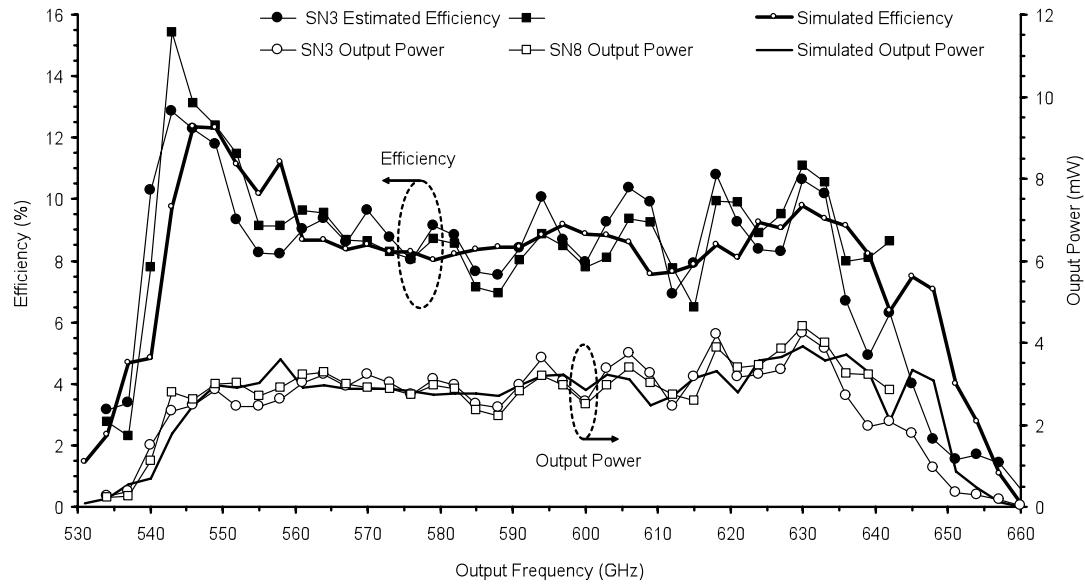
## I. FIGURES



**Figure 1.** This is the scheme that will be used to build the 1.9-THz source.



**Figure 2.** Schematic and measured results from the power-combined power amplifier module.



**Figure 3.** Measured data from a 600-GHz ( $\times 2 \times 3$ ) chain. Two of these multipliers will be power combined to enable  $>5$ -mW output power at 636 GHz.



**Figure 4.** A 1900-GHz tripler chip with two anodes has been designed and fabricated (as shown in the left). A close-up of the anode area is shown on the right.

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